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ART. I.—*History of the Invention of Pendulum Clocks by CHRISTIAN HUYGENS* *. By J. H. VAN SWINDEN, Councilor of State, Professor of Philosophy at Amsterdam, &c.

THE measure of time is of the greatest importance to civil society, and in many departments of science. An accurate one, capable of measuring its minutest parts, is essentially necessary for astronomy. Accordingly, different contrivances for this purpose have been of old devised; such as the clepsydræ of the ancients,—to which were substituted the motion of sand,—and afterwards clocks, furnished with wheels, and moved by a weight or spring. The latter were materially improved by the introduction of a *balance*, which regulated to a certain degree the motion of the wheels. Still the irregularities to which even the best of them were subject, were so great, that the most famous astronomers, such as Tycho Brahé and Hevelius, though they spared no trouble or expence in their construction, were com-

* The following is a somewhat abridged translation of a paper read before the First Class of the Dutch Institute, and inserted in the Third Volume of their Memoirs. Its chief value for the history of Science, consists in the number of hitherto unpublished documents which the author has collected from the manuscript papers relating to Huygens in the possession of the University of Leyden, of which large extracts are appended to the memoir. These are not attempted to be given here, but may be consulted by every one, being for the most part written in the original French and Latin languages. They are referred to in the translation by the words *Leyden MSS.* Short extracts of them have, however, been occasionally added in the notes, or incorporated with the text.—TRANSL.

pelled to acknowledge that no dependence could be placed upon them.

The use which might be derived from the oscillations of a vibrating body, first became apparent to astronomers, from the time that Galileo made known his theory of pendulums, partly by his letters, and *Systema Cosmicum*, published in Italian in 1632, but more especially by his *Dialogi de Motu*, which appeared in 1639. They applied this doctrine to measure the time which elapsed between two observations, by means of a ball, suspended to a wire or metallic rod, which oscillated by its own gravity when impelled; and we are truly astonished at the degree of accuracy of which this method became susceptible, in the hands of diligent observers. It was, however, subject to two serious inconveniences. The principal one was the necessity of assistants to count the number of oscillations of the pendulum, relieving each other at intervals, as the length of the observation, which sometimes lasted for twenty-four hours, required. This made some of them intent on the possibility of adapting to the pendulum something which might of itself indicate how many oscillations had taken place during the interval of observations. Hevelius affirms having succeeded in such a contrivance, (*Machina Cælestis*, i. p. 364.); and Wallis, in a letter to Huygens, (*Leyden MSS.*), says that somebody had added a wheel to his pendulum, which served the same purpose. Another defect consisted in these pendulums always returning to rest, after describing arcs which became continually shorter and shorter, so that after a certain period they required being put in motion again. Pendulums, then, in this state, could not be termed *accurate measurers of time*. In order to answer this end, some additional contrivance was requisite, which should, by its action, restore to the pendulum the loss of velocity suffered at each vibration, and thus render its motion perpetual, whilst itself should in its turn be kept to a regular rate, by being obliged to follow the isochronous beats of the pendulum, and become capable of showing off with accuracy, not only the smallest portions of time, but in like manner those longer periods which arise from the accumulation of them.

This required a genius of a particular cast. It appeared in the person of our countryman CHRISTIAN HUYGENS, a man of

rare talents, who, when yet very young, was already ranked among the first mathematicians of his age, and is still considered as one of the greatest that ever lived, and who, from his earliest studies, showed a turn for mechanics, which, united to his theoretical knowledge, peculiarly fitted him for the accomplishment of this difficult task. It was at the latter end of the year 1656, that Huygens first hit upon the idea of furnishing clockwork with a pendulum, and substituting the latter for the *balances* then in use. He immediately set about making one of this construction, and had many more made under his direction in 1657, for which he obtained, on the 16th of June, an exclusive privilege from the States-General. In 1658, he published a Latin description of his clocks, consisting of a few pages in quarto, under the title of *Horologium*, dedicated to the States of Holland. He also made known his invention to many of his friends, as appears from their numerous answers (*Leyden MSS.*), and he made an unsuccessful attempt to procure a similar patent in France. Scarcely had he constructed a few on this principle; till they were every where brought into use: the balances of many clocks, whether driven by a weight or a spring, were taken out, and pendulums substituted in their place; so that even before the above-mentioned Latin publication appeared, clocks were seen, having pendulums of twelve or twenty feet long, with weights upwards of thirty pounds affixed to them *, of which those of the church at the village of Scheveningen, near the Hague, and at Utrecht, may be reckoned among the first. His description of them was sent to his correspondents among the learned, and by them diffused in every foreign country, and spread with amazing rapidity. The proofs of this assertion are most evident, from the numerous congratulatory epistles addressed to him on the occasion, from people of all ranks and countries, accompanied with frequent requests of sending specimens of his newly invented clock, as constructed under his own

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* *Horologium*, p. 1. & 9.—The works of Huygens were first collected by s'Gravesande, under the title of *Huygenii Opera varia*, 1724, in quarto, with an account of his life prefixed; to which were added by the same, *Opera Reliqua et Posthuma*, in 1728.

superintendence, (*Leyden MSS.*) *; and astronomers from thence began to relinquish their former balance apparatus, which was soon entirely superseded by the pendulum clock.

Notwithstanding the important discovery thus made, it was to be expected, at a time when the application of mathematical theories to mechanics was far from being generally understood, that the principle of the new contrivance, namely, the reciprocal action of the wheels and pendulum on each other, (the latter regulating the former, whilst it is prevented by them from returning to rest,) would not be immediately and fully comprehended by all, but give rise to several objections. We must therefore enter into a more particular detail of the uses and construction of the balances, for which the pendulum came to be substituted, in order to show how greatly the old principle fell short of the new, in answering the end of a proper regulator of the work, confining our attention to that part of clockwork to which the invention more immediately belonged, and which is called the *Escapement*.

The old works, then, may in this respect be reduced to two classes. In the first, Fig. 3. Plate VII. the balance TT was supported on a perpendicular arbor MN, the pallets M and N of which acted on the teeth of an upright crown or balance-wheel LL. When Huygens substituted the pendulum, he only at first altered this arrangement, in so far that he fixed on the perpendicular arbor MN, Fig. 1. a pinion, or smaller wheel O, which not having a revolving but swinging motion, as well as the arbor itself, engaged by its leaves the teeth of a larger wheel P, supported on the horizontal part of the bent wire TQR, which transmitted the reciprocal actions of the pendulum and clockwork. By this contrivance, and because the diameter of the wheel P was double or treble of that of the pinion O, Huygens judged that small vibrations of the pendulum would keep the clock going, and that small irregularities in its motion could not disturb the uniform rate or isochronism of the work †,—an ex-

* Among these are letters of Mylon and Bouillan, distinguished mathematicians at Paris, Wallis, Jacquet, Gregorius a Sancto Vincentio, Kinner of Vienna, Slusius, and Pascal.

† *Horologium*, p. 12.—Fig. 1. is taken from the diagram affixed to the *Horologium*; only those parts are omitted which do not immediately concern the escape-

planation with which Wallis, who had at first entertained a doubt on this head, expresses himself perfectly satisfied. (*Leyden MSS*).

The second class of clockworks, Fig. 4. had the axis to which the pallets were affixed in a horizontal situation, whilst the balance TT moved in a vertical plane. In subsequently adopting this arrangement Fig. 2., it seems that the vibrations of the pendulum now directly receiving the impulse of the pallets, became too large, and that it was in order to obviate this defect that Huygens suspended the pendulum from a thread between two curved brass-plates, which, by arresting it at a certain point of its course, prevented its going too far on either side. This departure from the original construction was not then published by Huygens; but it must have occurred to him very soon after the publication of the first, whether with a view of adapting the new principle more easily to the then existing balance-works, or as a farther improvement of his own, (his activity and endeavours after perfection knowing no bounds, *nil actum reputans si quid superesset agendum*); for, in a letter of M. Mylon, dated Paris, 31st January 1659, his gentleman speaks of clocks, in which the axis lies horizontal, which, not having the pinion and wheel O, P, Fig. 1, are freed from certain inconveniences, but are liable to another, "which," he says, "namely the inequality of the lengths of the vibrations, and consequently of the time, you have endeavoured to correct, by the addition of those two small pieces." (*Leyden MSS*.) And Huygens himself, in a letter to Van Schooten, Professor at Leyden, of the 6th December 1659, says: "You know, I think, that I employed in my clockworks two curved plates, between which the pendulum moved; and that this was done, in order that the vibrations might all be made in equal times, as otherwise they would not be isochronous." After he had used them for this purpose, he discovered,

ment. The improved arrangement represented in Fig. 2. is taken from his work on the Theory of Pendulums, entitled *Horologium Oscillatorium*, which Huygens only published in 1673, though, (as will appear in the text), it had occurred to him at a much earlier period, and was actually adopted soon after the discovery of the first. It must be observed, however, that the plates or cheeks, between which the pendulum is suspended, were not at first of the cycloidal shape, which he afterwards adopted and explained in this latter work, but were intended for a different use, which is explained in the sequel.

that, in order completely to answer their end, they must be bent into cycloidal arcs, a discovery which he communicates in the same letter: "Quod igitur nunquam me inventurum speravimus, nunc denique reperi: veram nimirum figuram curvarum, quæ efficiat ut oscillationes omnes accuratissime exæquantur. Eam ratione geometrica determinavi — mihi quidem omnium felicissima (inventio) videtur in quas unquam inciderim." (*Leyden MSS*).

The decided advantages of the pendulum over the old balances to regulate the rate of clocks, were not however immediately perceived by all. In the first place, it was thought by some, that as clocks furnished with balances moved faster, according as heavier weights impelled the wheels, the same might be the case with pendulum-clocks. In the next place, balance-clocks stood still on being wound up, whereas Huygens, by his mode of suspending the weights, made his move on during this operation. In the third place, the reciprocal actions of the pallets and crown-wheel appear not to have been thoroughly understood by many. They imagined, that the irregularities in the motion of the wheels might perhaps in this manner communicate themselves to the pendulum, instead of being overruled and prevented by it*. Lastly, the inequalities in the lengths of the vibrations would alter the isochronism, an objection which Huygens was himself the first to make; but he shows at the same time that his manner of connecting the pendulum with the work, made these small anomalies imperceptible. (*Horologium*, p. 12.)

The attention of astronomers about this time was generally directed towards finding some means of rendering clocks more regular. Hevelius, who had already, it seems, devised some method by which the pendulum itself might indicate the number of oscillations it had gone through during a certain time,

* Abundant proofs of this occur in the letters of his correspondents, (*Leyden MSS*). The objection is stated in the most forcible manner by Jacquet, in a letter from Antwerp, 1658: "Unus mihi scrupulus inhærit, pendulum tuum non tam suo, quam automati motu, cieri. Cum enim pendulum liberum neque vibrationum arcus sortiatur æquales, neque motum per se continet, utrumque autem tui automati beneficio consequatur, manifestum videtur illud agitari potius automati motu artificiali quam naturali suo.—Manet dubium annon plus inæqualitatis de machina in motum penduli, quam æqualitatis ex motu penduli in machinâ derive- tur," &c.

appears likewise to have been intent on the means of rendering its motion perpetual, and even to have *endeavoured* to connect it with his clocks: "But," he adds, "whilst working at them, and before they were completely finished, it happened that Huygens had in 1657 invented *similar* clocks, and published a description of them in 1658." (*Machina Cœlestis*, p. 366.) In a manuscript paper in Huygens's own hand, containing short remarks on his principal discoveries, under the title of *Anecdota*, (*Leyden MSS.*), he only says of Hevelius, that he had made attempts for himself: "Hevelius sibi occœpit." Hook appears likewise to have found out a means of rendering the motion of pendulums perpetual, but it was no application of them to regulate clocks. (*Hook's Works* in fol. p. 4.) Many, in short, sought after something,—Huygens alone hit upon the true principle. He was far from denying, however, that the loose or detached pendulums brought into use for astronomical purposes by Galileo, had suggested to him the use which might be made of them to regulate clocks, (*Horologium*, p. 1.); nor did he conceal that the common balance-clocks prevalent at that time, had furnished the ground of the escapement, and that he only altered them so far as was necessary to adapt them to the action of the new regulating principle. (*Ibid.* p. 7.)

The description given by Huygens of his clocks, as likewise the clocks constructed by him, or under his inspection, soon taught clockmakers here and elsewhere to substitute the pendulum for the balance in existing works. Many, however, did not succeed so easily*; and although Wallis wrote Huygens, (*Leyden MSS.*) that, before receiving his description, he had seen in England a clock with a pendulum, which was, however, known to be of his invention, and added, in a subsequent letter, that several English watchmakers imitated them each in his way, from which it would appear, that, very soon after the invention;

* The numerous letters of M. Petit, Intendant des Fortifications et Ingénieur du Roi, to M. Huygens, form an amusing part of the collection in the Leyden MSS. He could not for a long time succeed in fitting up a clock in his possession, so as to make it go; and though he wrote letter after letter for advice, and added weight after weight to move the wheels, his difficulties seemed rather to increase; and he was for several years the most troublesome correspondent of Huygens, whom he professed to admire very much.—*Note of the Translator.*

pendulum-clocks were constructed in England; still the number of them must have been small: for Derham, an Englishman, who published a work on watchmaking in 1700, says, that after Huygens had invented pendulum-clocks, and made many of them, a Dutch watchmaker of the name of Fromentil came over from Holland about the year 1662, and constructed the first ever seen in England. He adds, that there was still one extant in Gresham College, which Bishop Seth of Salisbury had made a present of to the London Society. This, however, I am disposed to think relates only to pendulums with cycloidal cheeks. Huygens himself mentions, in a journal of his voyage to England in 1661, that Mr Goddard had, on the 6th of April of that year, at a meeting of the Society at Gresham College, shewn him in his apartments three fine pendulum-clocks.

Some watchmakers in Holland, who, notwithstanding the privilege of the States granted to Huygens, imitated his pieces, concealed as much as possible the new device, and went even so far as entirely to dispute his claim to the discovery. He complains of this abuse in the dedication to the States of Holland, prefixed to the *Horologium*; and was even compelled to prove his claims in a lawsuit, which he directed his workman Ooster to institute against a watchmaker at Rotterdam.

This, which took place in Holland under Huygens's eye, was much more to be expected in foreign parts, and actually happened at Rome, where the description published by Huygens had been sent at the end of 1658. Ægidius Gottignies, a professor at the latter place, wrote in August 1659 to Gregorius à Sancto Vincentio at Ghent: "One of these days, a watchmaker to the Pope constructed a clock similar to that of which Huygens sent you the description. He was highly elated with this new and admirable invention, which he said was his own, and had asked all mathematicians to come and see it. All were loud in their praises. For as he had prudently concealed the chief contrivance, so that the spectators saw nothing but the hands and pendulum, they were astonished, and could not sufficiently testify their admiration of a thing of which they had heard nothing, and bestowed the greatest applause on the pretended discoverer, when I, who had been admitted among them by Father Athanasius Kircher, suddenly checked these

plaudits, by mentioning the name of the author, and exposing the hidden artifice. Father Kircher has asked me to instruct a workman how to make such a clock, which I undertook to do." (*Leiden MSS.*)

But we come to more serious attacks on the rights of Huygens to be considered the inventor of pendulum-clocks. These arose more especially in Italy, where the invention has been ascribed to Galileus Galilei, and his son Vincenzo Galilei. As this claim has been asserted in several works, even of the present day, and with some appearance of reason, it becomes necessary to show, from original documents, how far Galileo and his son had gone, and to examine the real truth of the above-mentioned assertions. This is the chief purpose of this paper; and I flatter myself to be able to set the whole matter at rest for ever; and, far from detracting any thing from the just claims of Galileo, to place these, on the contrary, in their proper light, by pointing out, in a much clearer manner than has ever yet been done, what Galileo actually accomplished.

I shall first state the nature of the claims set up against Huygens, before entering upon a critical examination of them.

They may be learned from the introduction to the *Horologium Oscillatorium*, published in 1673, where, in a firm, though moderate manner, he asserts his right to the honour of the discovery, "Nunc cum hæc omnibus nota sint, (namely, that he, Huygens, had fitted up clocks with a pendulum as early as 1657, and sent specimens of them, along with a printed description, every where the following year,) facile apparet quid de illis existimandum sit qui septem post annis eandem constructionem, quasi a se suisve amicis profectam libris suis venditarunt." It was probably after reading these words, that Prince Leopold de Medicis wrote in 1673, the letter quoted by Tiraboschi, from the *Lettre inedite d'Uomini ill.*, and addressed to Huygens: "*Per quello che riguarda all' invenzione del pendole, con asserzione dettata da animo sincerissimo, costantemente le affirmo di credere mosso da un forte verosimile, che à notizia di v. s. non sia per alcun tempo venuto il concetto, che sopravvenne ancora al nostro Galileo di adattare il pendolo all' oriole; poiche ciò era e pochissimi noto, et l'istesso Galileo non avea ridotto all' atloo pratico cosa veruna di perfetto, a tel conto, come si vede*

da quel poco che fu manipolato ed abbozzato dal figliuolo." To which Huygens, according to the same writer, would have answered: "*Il faut bien croire pourtant, puisqu'un tel Prince l'assure, que Galileo ait eu auparavant moi cette pensée?*" (*Storia della letteratura Italiana*, t. viii. p. 156.) This letter of the Prince I have not found among the papers in my hands. The words above quoted from Huygens, relate to what Count Malvasia had published in his *Ephemerides*, printed in 1662 at Florence, that he possessed at his house a clock, "the motion of which was regulated by a pendulum, according to the manner discovered at Florence some years before." This does not prove that this clock existed before the publication of Huygens's description, but merely that Malvasia considered the application of pendulums to clocks as an invention of the Florentines. Nor does he attribute it directly to Galileo; but he certainly takes it away from Huygens. That the Florentines claimed the discovery, was not new to the latter, since, already two years before, he had received from Rome a letter, (dated March 1660,) in which the writer informs him, that he had heard at Florence that pendulum-clocks had been invented there for some time, and that somebody had even sketched out to him in a rough manner what Galileo had attempted to make on that principle. Nor was he ignorant of what Prince Leopold de Medicis wrote in April 1659, to Bouillan at Paris, from whom he had received a copy of the description of Huygens, namely, that the application of the pendulum to clocks had been a subject attended to at Florence for three years, and that an artist had made a clock, which he (the Prince) hoped would succeed. Consequently this work had not yet been perfectly finished. Extracts of that letter were sent to him by Bouillan, (*Leyden MSS.*) and this latter gentleman, upon receiving Huygens's answer, expresses himself highly satisfied with it, and sent his own words to the Prince, who, in a subsequent letter, acquits Huygens entirely of the charge of having wilfully attributed to himself the discovery of Galileo, (*Ib.*) This defence of Huygens to Bouillan would throw much light on the subject; unfortunately it has not come down to us, and he himself seldom kept minutes of his letters; but very rarely we find short remarks subjoined to letters

which he had received, and which probably contained an outline of the answers he had made to them.

What follows relates no doubt to the statement found in the account of experiments made at Florence, under the title of *Saggi di Naturali Esperienze*, which had appeared in 1667, "Qui vero Galileo primas hic deferre conantur, si tentasse eum, non vero perfecisse inventum dicant, illius magis quam mee laudi detrudere videntur, quippe qui rem eandem meliori quam ille eventa investigaverim. Cum autem vel ab ipso Galileo, vel ab ipsius filio, quod nuper voluit vir quidam eruditus, ad exitum perductum fuisse contendunt, horologiumque ejusmodi re ipsa adhibitum, nescio quomodo creditum sibi iri sperant, cum vix verisimile sit adeo utile inventum ignotum manere potuisse annis totis octo (1649,—1657,) donec a me in lucem ederetur." (*Horol. Oscillator.*, p. 32.) The Secretary of the Academy del Cimento, then Count Lorenzo Magalotti, had said, p. 22. of the *Saggi**, that the academicians (in order to measure the time accurately,) had "thought proper to add a pendulum to a clock, after the example of what Galileo had found out the first of all, and his son, Vincenzo Galileo, had put in practice as early as 1649." The claims of Galileo to the invention could not possibly be asserted in stronger terms. A figure is added of the clock, as employed by the academicians of Florence, but this only shows the external appearance of the instrument; besides they do not tell us whether this agrees exactly with the original, as constructed by Vincenzo Galileo, and pendulum-clocks existed already at the period of this publication in Italy, where the description by Huygens was likewise every where known.

This is not all. In 1680 appeared a man, who roundly denied that Huygens ever made any discovery about clocks at all. This was no other than Becker, well known for having originally suggested the system which so long prevailed under the name of Stahl. In February of that year, he presented to the Royal Society of London a treatise *De Nova Temporis dime-*

* This work, in folio, was translated into Latin, with notes, by Musschenbröek, and published in 1731, under the title of *Tentamina Naturalia Academia del Cimento*, in quarto.

*tenendi ratione, et accurata horologiorum ratione**, in which he thus expresses himself: "M. Huygens of Züllichem, a Hollander, claims the invention and practical application of pendulum-clocks, in his treatise dedicated to the States of Holland, from which he afterwards obtained an exclusive privilege, as likewise from the King of France." (This is inaccurate; the privilege was of the States-General, and granted the year *before* the publication; nor did he obtain the privilege from the King of France, though he applied for it). "But Count Magalotti, Resident on the part of the Grand Duke of Tuscany at the Imperial Court, contradicts him, who told me in person the whole history of that clock; the same was told me three years ago in the same manner at Augsburg by Trefler, watchmaker of the late Grand Duke †, father of the present. Namely he relates having, by order of the Grand Duke, and in the spirit (*instinctu*) of his mathematician Galileo Galilei, made the first pendulum-clock (*Horologium Pendulum*) at Florence, of which a specimen was sent to Holland. The mathematician of the late Elector of Mentz, told me he had seen at Prague a pendulum-clock, made by Justus Borgen, mathematician and watchmaker to the Emperor Rudolph II., of which the great mathematician, Tycho Brahé, had made use in his astronomical observations." This statement of Becker has found its way into several works, and has been admitted, without farther inquiry, by some as containing facts uncontroverted by any species of evidence, except the known integrity of Huygens, by others as undoubted truth, and farther commented upon in an eulogy on Galileo, originally published at Milan, in an Italian Journal *del Caffè*, afterwards in the third volume of *Elogi degli Uomini illustri di Toscana*, printed at Lucca in 1772. The writer of this last work, in men-

* Reprinted in the *Physica Subterranea*. The judgment of Flamsteed and Hook upon it was any thing but favourable. See Birch's *Hist. of the Royal Soc.* iv. 17. Leibnitz drew a still worse picture of the man, Op. vi. 333. His language about Huygens appears certainly not very creditable, after he had, in 1660, on a visit to Holland, requested the honour of his acquaintance, to shew him a *perpetuum mobile*, with some little flattery to a man, "Quem in Mechanicis ob Horologium a te (Huygenio) inventum celebrari intellexit." (*Leyden MSS.*)

† Ferdinand II. dead in 1670; he was brother of Leopold de Medicis, before mentioned.

tioning that Galileo, in his old age, had added a pendulum to clocks, after adding the words of Becker and those of Magalotti, in the Experiments of the Academy *del Cimento*, concludes thus: "Lastly, We possess the letters of Galileo to Beaugrand, with others of Reaal and Hortensius, which, besides Viviani, prove, in an indubitable manner, that Galileo really made the application of the pendulum to clocks. It is Elia Deodati, who, in 1637, sent an account to the father of the celebrated Huygens, of the pendulum-clocks constructed by Galileo; and Becker adds, that a model was likewise sent to Holland. All this is sufficient to refute Huygens, Musschenbröck, and many others, who will not allow Italy the honour of these great discoveries*."

It is impossible to meet with more unqualified charges, and if, after the lapse of centuries, nothing should remain on the subject but the writings of Becker and of this eulogist, one would be compelled to refuse Huygens all share in the application of the pendulum, and perhaps to refer it to an earlier period than Galileo himself,—so difficult it is sometimes to ascertain the truth in the history of science. What, then, are we to think of the opinions of older philosophers, as described by historians, panegyrists, and other writers, when such uncertainty exists respecting a discovery a little more than one century and a half old?

To these bold assertions I shall now oppose the evidence of *facts*, which I have arranged under the five following heads:

In the *first* place, By showing that the correspondence of Galileo contains not a word of the pretended application of the pendulum to clocks.

Secondly, By disproving, what is hinted at, that Huygens learnt the application made by Galileo through the letters of his father, or by a model from Italy.

Thirdly, By exhibiting, what has never been done yet, the actual clock, as devised or made by Galilei and his son Vincenzo, from papers hitherto unpublished, and shewing that Huy-

* This work on Galileo has been literally copied in the Geneva edition of the *Encyclopédie*, in quarto, by Pellet, and the octavo edition, under the word *Galileo*, where it is attributed to Frisi. This is false; the *Elogio de Galileo* by Frisi, of which more hereafter, is a totally different work, and contains altogether different views from those here expressed.

gens neither had nor could have the least knowledge of it. This, I believe, will show Galileo to have accomplished even something more than what his most zealous defenders have brought forward to this day.

Fourthly, By proving the narrative respecting Trefler in Becker's work to be greatly exaggerated, and that the most probable circumstances in it must, from their very nature, have been unknown to Huygens.

And, *lastly*, By explaining the origin of those pretended pendulum-clocks employed, it is said, by Tycho Brahé, whose death had taken place more than thirty years before any thing respecting Galileo's attempts were made known.

1. With regard to the letters of Galileo to Beaugrand, there is found but *one* in the quarto edition of his works in Italian of 1718, dated November 1633, in which, speaking of the longitude, he mentions the necessity of having accurate clocks, (*giusto orologio*,) "which I construct with so much facility, precision and simplicity, that they do not admit of an error of a single second, not only in an hour, but even in a day in a month." Whether there be others in the *Lettre inédite d'Uomini Illustri*, by Fabroni, I have not been able to ascertain; but they cannot possibly contain more information than those which we are next to examine, and which were written professedly on the subject hinted at in the above letter to Beaugrand.

These are addressed to Reaal, formerly Governor of India, a man of great merit, knowledge, and authority in Holland. Hortensius, Professor of Mathematics at Amsterdam, the celebrated Grotius, and the States-General, and relate all to the discovery which Galileo had made of the Satellites of Jupiter, their eclipses, and his method of finding the longitude by means of them. After having applied in vain for the support and countenance of the Court of Spain, he resolved, in 1635, to offer his discovery to the States-General of the United Provinces. This correspondence, which was carried on chiefly through the medium of Deodati, at Paris, and Grotius, is contained in his works, to which may be added the *Epistola Grotii*. In his first communication of March 1636 to the States, he enumerates the requisites for making a good observation at sea, and mentions as one an excellent clock "*esquisito orologio*," to count the

hour, with its smallest divisions, (*minurie*,)” from noon, or from the setting of the sun. Of which he says, “ I possess *measures of time (mesuratore del tempo)* such, that if one constructs four or six similar instruments, one will find, as a proof of their accuracy, that the times which they measure and indicate (*tempi da quelli mesurati e mostrati*,) do not differ one second, not only in an hour, but a day, a month; so uniform are these *clocks (oruoli)*, fully (*pur troppo*) astonishing to observers of celestial phenomena and motions; the more because the construction of those instruments (*strumenti*) is very easy and simple, and little subject to those external hindrances which other instruments devised for the same purpose are liable to.” The word *oruoli* (horologes,) which here occurs, must be particularly attended to; for though it suggests to us, and did even suggest at that time the idea of an instrument indicating the time by the regular motion of the hands, it appears from Galileo’s own description of them, in a subsequent letter, written in June of the same year, that he meant something quite different from it. After explaining the chief principles of this theory of the pendulum from his *Dialogi de Motu*, (which were then printing at Elzevir’s,) he adds: “ From these true and well established principles, I derived the construction of my *reckoners of time (numeratore del tempo)*, and I use not a weight, suspended by a thread, but a pendulum (*pendole*) of some ponderous and more solid stuff, (*de materia solida e grave*,) as brass or copper: I make the pendulum in the form of a sector of twelve or fifteen degrees, its semidiameter of two or three palms, (between sixteen and twenty-four inches,) the larger it is the more easy will it be to be employed (*con minor tedio se gli potra assistere*). I make this sector thick in the semidiameter of the middle, and becoming thinner towards the edge, by which means I obtain a cutting side, which will enable it to overcome, as much as possible, the resistance of the air, which alone retards its motion. In the centre is a hole through which an iron axis passes, like that of a balance, with a sharp edge below, resting on two supports of bell-metal.” “ It will be necessary,” he farther adds, “ in order to continue its motion, that an assistant shall, from time to time, give it a pretty strong impulse, (*un impulso gagliardo*), to restore the length of its vibra-

tions." But as the same assistant has to count the number of oscillations which it performs, he proposes, as a tolerably easy mode of avoiding this troublesome labour, (*un assai comodo provvedimento*,) that from the middle of the vibrating sector there should project a pin, which, when the pendulum swings to one side, should meet the upright part of a tooth belonging to a small crown-wheel, as light as paper, (*leggierissima quanto una carta*,) and impel it round its axis, but on swinging backwards, ascend along the sloping side of the same tooth, and leave the wheel unmoved; so that one tooth might be impelled at each entire vibration, and the number of vibrations be shewn by the revolution of the wheel, which might likewise be connected with a larger wheel by means of a pinion." "But," he adds, "it is unnecessary to explain all this to you, who possess choice and practised artists in the construction of clocks and other machines; because those people, on learning the new principle, that a pendulum performs its oscillations in very equal times, whether it describes larger or smaller arches, will be able to draw from it much more *subtile* consequences than I can imagine." From this it appears doubtful, whether Galileo ever himself tried the contrivance of the pin and wheel, and did not rather throw it out as a hint for others to improve upon, than as the result of actual experience. He then concludes in these remarkable words: "In these very simple pendulums, then, which are subject to no alteration whatever, (*alterazione alcuna*,) is contained the method to preserve in an easy manner a constant measure of time: and you will perceive their utility and the advantages they possess in astronomical observations, which do not require that the *orologio* should always go, but where it is sufficient to know from the hours of noon, or of the setting of the sun, the smaller divisions of time, for an eclipse, conjunction, or other celestial phenomenon."

These extracts need no comment. They prove abundantly that the word *orologio*, though used long before that period, to express a clock moved by wheels and weights, was the name adopted by Galileo to designate this loose pendulum, the invention of which, as the measure of time, belongs undoubtedly to him. That it continued to be called by that name for some years after, is manifest from a French work, printed at Paris in 1639,

bearing the title *L'usage des Quadrans ou de l'Horolôge Physique Universel*, and which treats of nothing but free or detached pendulums; it is in fact an extract from the Theory of Galileo.

The States-General, on receiving the propositions of Galileo, appointed Commissioners to examine them, presented him with a golden chain, as a token of their regard, and promised greater rewards, if the invention should be found to succeed. The negotiations, however, were interrupted by the successive deaths of all the Commissioners, and finally put a stop to by his own death, which happened in 1641.

I conclude, then, that those who appeal to the correspondence of Galileo, have either not examined the letters, or been deceived by the twofold circumstance of his employing a pendulum, and calling it by the name of *Oruolo*; and that at least from 1636 to 1639, Galileo had not yet either accomplished or indicated the application of the pendulum to regulate the motion of clockwork.

(To be concluded in next Number.)

ART. II.—*Observations on the Countries of Congo and Loango, as in 1790.* By MR MAXWELL, Author of the Letters to MUNGO PARK, &c. &c. (Concluded from Vol. VI. p. 62.)

CANOES.—AT Cape Lopez and Jabon, the canoes are formed out of single trees of red-wood. They are flat-bottomed and wall-sided. I have seen some of them seventy feet long, six broad, and four deep, capable of holding a considerable number of people. I am told of one belonging to King Passéall, at Cape Lopez, that holds two hundred men.

HOUSES.—The construction of these, though simple, is very ingenious. The body of the house consists of four parts, the ends and sides, each made separately of bulrush-stems. The bulrushes, which are about an inch in diameter, are first cut of the proper length, and laid parallel to one another upon the ground; they are then secured in this position by transverse branches of bamboo at the ends and in the middle, three or

OLD PENDULUM
V BALANCE ESCAPEMENTS.

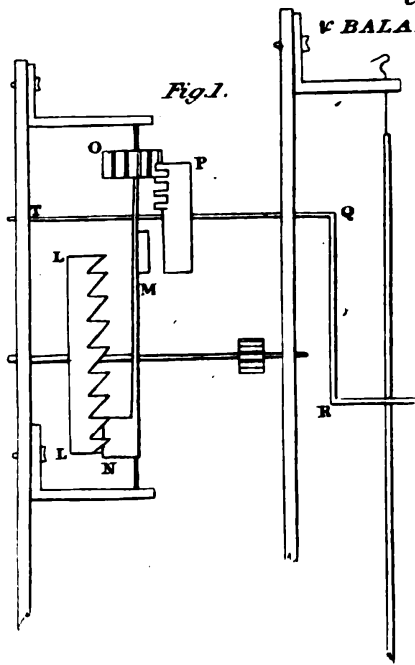


Fig. 1.

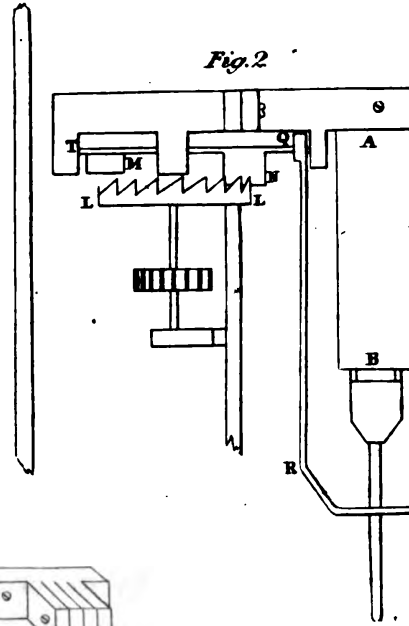


Fig. 2.

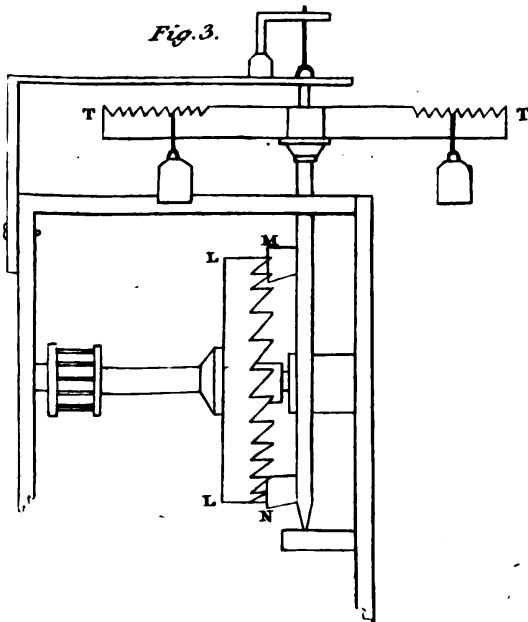
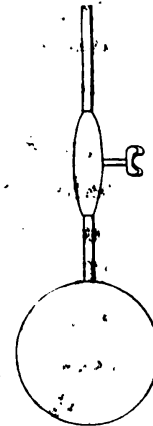
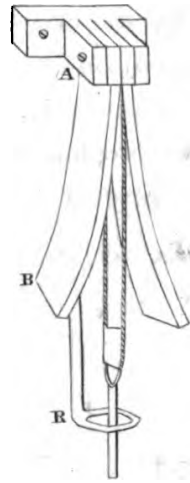
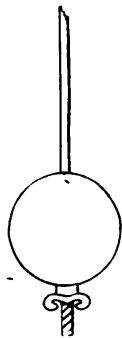


Fig. 3.

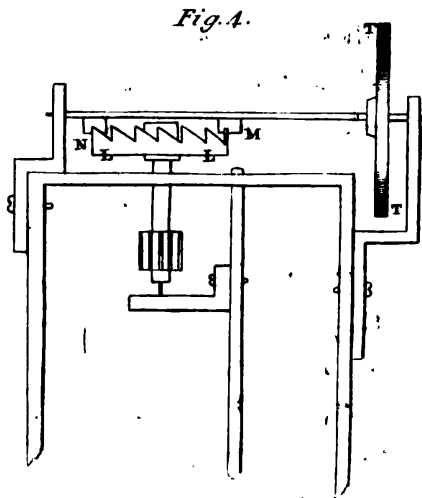


Fig. 4.

quently pursued in vain, till at length the party were successful enough to overtake a couple of them. One of these beasts was shot near the mountain of Papandayang, and the other close to Mount Talaga Bodas. Both are secured to increase the collection of natural objects, which this successful journey has procured for the Museum, already so extensively enriched by the enterprise and scientific ardour of the Professor and his companions.

ART. V.—*History of the Invention of Pendulum Clocks*. by CHRISTIAN HUYGENS. By J. H. VAN SWINDEN, Councilor of State, Professor of Philosophy at Amsterdam, &c. (Concluded from Vol. VI. p. 213.)

BUT, it has been said that Huygens got intelligence through his father and Deodati of Galileo's labours. It is true, Deodati wrote to Constantine Huygens, father of the philosopher, and Secretary to Prince Frederic Henry, pending the above negotiations with the States General; for his letters are of the year 1637, but they contain only the same intelligence which has already been given (See Galilei Op. iii. p. 432.); and Huygens could learn nothing more than what shortly after appeared in the *Dialogi de motu*, except perhaps his notion of the pin and wheel, to indicate the number of oscillations without the trouble of counting them,—a thing as totally different from the principle adopted by Huygens to regulate clocks by means of the pendulum, as any of the attempts of Hook and Hevelius, who, however, never claimed the discovery of its application to clocks. And as to a clock or model having been sent over to Holland; we only learn, from a letter of Deodati of the same year, that if the States desired, Galileo would send what he had promised, to wit, “a very perfect telescope, with the method he had found of using them on board vessels, whilst in an agitated sea; the observations about the motions of the satellites of Jupiter, and the construction (*fabricam*) of the very accurate *horologium* invented by him; and that he would explain all his inmost thoughts on this subject in words and writing.” This

manifestly refers to the description already given above. The mistakes on this subject have arisen probably from a prevailing notion, that Hortensius, the Amsterdam professor, had been actually dispatched to Italy. This is confidently asserted by Brucker, in his *Historia Philosophia*, vol. v. p. 678, and has been copied in Bailly's *Hist. de l'Astron. moderne*, and Montucla's *Hist. des Mathematiques*. The fact is, that Hortensius never departed on this voyage, though great preparations had been made, and the States had granted 2000 guilders for it; it was first delayed, and then prevented by his death. Of the truth of this any one may be convinced, who will be at the trouble of perusing the letters of Vossius and Grotius, written, it must be remembered, about twenty years before Huygens claimed any invention, or before any controversy on the subject could arise.

3. Of more consequence appears the direct assertion in the Acts of the Academy *del Cimento*, which we quoted before, that the idea of conjoining the pendulum with the clock had been first of all conceived by Galileo, and actually put in practice by his son Vincenzo Galilei in 1649. I have already, I believe, abundantly shown, that, in his communication to the States, Galileo had suggested nothing that can with propriety be termed a *clock furnished with a pendulum*, the only contrivance to which Huygens lays claim. His last letter is of the 30th December 1639, but he may, before his death, in 1641, have made the discovery, or his son, on the suggestion of his father, may have found it. From what I am enabled to produce on this head, it appears to me unquestionable that Vincenzo did accomplish, or endeavour to accomplish something.

We need not go back to the period of 1636, to which the supposed invention of pendulum-clocks was referred by Prince Leopold de Medicis, in the same letter to Bouillau, the friend of Huygens, of which an extract was given in the earlier part of this narrative, except to remark once more how egregiously Galileo's communications to the States-General had been mistaken. Indeed, so little have these been looked into by the writers who profess to found their claims upon them, that Brenna, in his life of Galileo, (in Fabroni's collection of *Vite Italianorum excellentium*), quotes the very letter which I have extracted under the first head, and says of it, "De fabrica atque usu

Horologii pendulo muniti, quod ipse excogitaverat, admodum luculenter ac diserte loquitur," a clock furnished with a pendulum, when the letter contains in reality the description (in Galileo's own words) of a free pendulum, a vibrating sector. I shall only quote one passage more from the above mentioned letter to Bouillau, in which the Prince says, "Having seen a model constructed by Galileo, differing somewhat from that of Huygens in the disposition of the wheels, (in parte deverso circa la constitutione della ruote)," (Leyden MSS.); because this (which probably regards Galileo's son as much as himself, who was blind after 1639,) agrees with what had been written to Huygens from Rome in 1660, about a rough sketch of a clock attempted by Galileo, and also with the account of the academicians *del Cimento*, and is besides confirmed in a striking manner by Frisi, in his *Elogio del Galilei*, Milan, 1775, where he mentions Leopold's opinion, that Galileo had put nothing into practice equal to the invention of Huygens, "as might be seen from the little that had been contrived or sketched out by his son." "And truly," he adds himself, "the machine of 1649, was nothing but slightly sketched (*non era che un poco d'abbozzo*)." He seems to think that the clock represented in the experiments of the academicians was made after this model: this is not probable, as they are of a much later date.

After mentioning the concurring testimony of these writers, that something had been made or sketched by Galileo or his son, I have now the satisfaction of presenting to the class a *fac simile* of the drawing, representing the contrivance in question. (See Plate I. Fig. 5. and the Notice at the end of the article). It was found by me among the papers relating to Huygens, in the Leyden Library: There is written upon it, in Huygen's own hand, *Missa a Ser. Principe Leopoldo ad Bullialdum ab illo ad me: R. 15. Jan. 1660, cum descriptio mei Horologii edita fuisset, A. 1658*; and in another hand, which I recognise for that of Bouillau, these words, *Horloge commencé par Galileo Galilei*; and on the reverse by the same, *à Monsieur Monsieur Christian Huygens de Zulichem à la Haye*. Among the letters of Bouillau, there is a corresponding one of the 9th January 1660: "I send you the figure of the pendulum-clock begun by Galileo, as it was sent to me from Florence; and another of the 29th February. You may keep

the drawings: I kept the copies sent from Florence; I had yours made after them." (*Leyden MSS.*)

It is manifest, from the mere inspection of the figure, that the drawing was made in a very coarse manner: I suppose, therefore, that the lowermost wheel had teeth on its whole circumference, though but one-half is represented, and likewise that the next following or middle wheel was divided equally by teeth every where, though a part here consists of merely a few hasty strokes; probably to meet the convenience of the artist who drew them. The axis to which the pendulum is affixed, and which moved with it, has a short bent lever, reaching to a number of studs or pins, projecting from the side of a sort of ratchet wheel, the teeth or incisions of which are equal in number to the pins. Above this wheel appears a crooked lever, fixed at one end, on which it turns, and seeming to rest with the other extremity against the axis or end of the pendulum, somewhat like a spring: it is also furnished with a projection, in the form of a cross, to enable it, as it would seem, to catch in its descent the teeth of the wheel. Farther, there appears neither spring-barrel nor cylinder for a weight. The only indication that can be found of its having been moved by a weight, is perhaps to be traced in the axis of the uppermost wheel, a part of which has an indistinct appearance of grooves cut into it, as if a rope or chain were to be wound round it.

As to the action of this machine, I can conceive the short bent lever to strike against one of the projecting pins, impelling it either in the one direction or the other, whilst the pendulum is swinging to one side; but I do not so easily perceive the way in which, on swinging backwards, it should fall in with the next following pin; and supposing this to be possible, then it is inconceivable to me how the loss suffered by the pendulum in its passage through the air and by friction, could be exactly compensated, as happens in the clock of Huygens, by the reciprocal action of the crown-wheel on the pallets, a contrivance of great ingenuity, which was not at first clearly understood by all. Whether Vincenzo Galilei greatly improved upon the design of his father, is doubtful, for it is of his attempt in 1649, that Prince Leopold and Frisi speak, when they call it a sketch (*abbozza*), and a slight sketch (*un poco d'abbozza*). But, however

this may be, the above mentioned dates are sufficient to show that Huygens had no knowledge of it when he published his description. In his *Ancodota*, written by himself, he only says: "Post nostrum libellum in Italian demissum figuram per Bullardum a Cardinali Mediceo (Principe Leopoldo) missam quam Galilei alteram; sed difficili machinatione, ut non mirum non successisse." (*Leiden MSS.*)

4. We next come to Becker's narrative of his having, about the year 1677, met at Augsburg, Trefler, watchmaker of the Grand Duke of Tuscany, at the period we are considering, who told him he had been the first who made a pendulum clock (*horologium pendulum*), at Florence, in the spirit (*instinctu*) of Galileo Galilei, of which a specimen was sent to Holland. A remark here naturally suggests itself, why no mention is made of his son Vincenzo, who is admitted by all the Italian writers either to have actually directed Trefler in the construction of the work attributed to him, or at least to have a prior claim to an attempt of the same nature. It might lead us to suspect that the whole statement refers to the much earlier period of 1636, and alludes to the single pendulum offered by Galileo to the States-General, and called by him, as we have already seen, *orologio*, of which Trefler, being a workman, might have made the first; and this would reconcile it to what is added of its having been made in Holland, as the only communication on the subject was made at that time.

But I shall not dwell on this conjecture, as something was certainly made afterwards by this Trefler, though the date and history of its construction are involved in great perplexity. That a clock with a pendulum, bearing the name of Trefler as maker, was produced, we have not only the authority of Eribi (*Elagio*, p. 129,) but the testimony of Perelli, Professor of Mathematics at Pisa, who gave a description of it (*Viraboschi*, p. 167.), which, however, I have unfortunately not been able to procure. The clock was said still to exist at Pisa in 1774, and may possibly have been preserved to this time. The Italian writers differ very much as to its origin. Perelli and Brenna (*Vita*, p. 77.) think, that it is the very clock devised by Vincenzo Galilei, on the suggestion of his father, and executed under his direction, by Trefler, in 1649. Others, however, maintain,

that Galileo had, indeed, in 1641, proposed the application of pendulums to clocks, that his son had endeavoured, with the assistance of one Dominice Balestri of Florence, to put it into practice; but that his death (which happened in 1649, eight years after his father's) had prevented him from seeing it executed, and that only several years afterwards Treffer had accomplished it, "though somewhat in a different way from what he had intended." (Tiraboschi, p. 155.) The accounts which these writers have left us of the clock in question, go a great way to strengthen a suspicion, that it was either wholly made after the construction of Huygens, or altered, in so far as respects the pendulum. Frisi says in as many words, that except the spring-barrel and fusee, the disposition of the wheels was exactly the same as in the clocks made by Huygens; it had likewise the bent plates or checks, which, whether cycloidal or not, are unquestionably an invention of Huygens. Frisi allows the work to be his, and Perelli admits the curved plates to be an addition of a later date, and Brenna, after acknowledging the same, seems very much puzzled how to account for the rest. It is quite possible that an existing clock should have been altered by Treffer, and a pendulum adapted to it after the manner of Huygens; many examples occur of the same, as we shall presently see. But I must first remark on the improbability, that if Treffer had really made a pendulum-clock, and a good one, on principles of construction discovered either by himself or the Galileos before Huygens, these clocks should have been so little known in Italy, at Rome, even at Florence itself, as they appear to have been at the period of Huygen's work becoming known in those parts of Europe. The letters among the Leyden MSS. leave no doubt on that head. We find from Bouillau's letters, that it was first sent to Florence in the autumn of 1658; on the other hand, we learn, from the words of Prince Leopold, communicated by that gentleman to Huygens, half a year later, and which have already been given, that after three years' attention to the subject, an artist had made one, which he *hoped would succeed*. Now, we may ask, why this doubtful language, and why these attempts, of the issue of which they confessed themselves uncertain, if Treffer had already accomplished the construction, and it had proved to be good? There

can scarcely be a stronger proof, that whatever might have been the attempts of the Florentines, they had till this time very little succeeded. Yet Huygens's book and specimens of his clocks had been sent every where, and had been known for more than a year; and at Rome a workman even excited surprise by it as an unheard of invention, and gave it out for his own!

All this seems to me to confirm in a striking manner the priority of our countryman's claim to the perfect adaptation of the pendulum to regulate clocks, and to corroborate the suspicion I stated before, that the specimens of Florentine clocks, to which so much importance is attached, were in reality made after the knowledge of his construction had gone abroad; and it must be remembered, that it was in 1657 that he already made his clocks, though the description was published a year later. Even the Italian writers, who contend for the fame of the Galileos, admit that Huygens first of all brought their attempts to perfection. (See *Brenna Vita*, p. 80.; and *Tiraboschi*, p. 157.) Now, it is quite natural, that, as soon as it was understood that he had discovered a way of applying the pendulum to clocks, even though his method were not precisely known, many would try to make a similar attempt at such a contrivance, at a time when a general wish existed among people conversant with the subject for an improvement of the pendulum. And this was most likely to happen at Florence, where the pendulum had been originally proposed as a measure of time, and where interest in the subject had been kept alive through the remembrance of Galileo, and the attempts of subsequent artists. The substitution of the pendulum in existing clocks was not a matter of so much difficulty, when once the mode of its action was understood; and it soon became a general practice to take out the old balances, and place pendulums instead of them.

Nor is this, in reference to the Florentines, a conjecture unsupported by any kind of presumptive evidence. From what I am now going to state, it appears that something of the nature described was actually taking place in Florence about the time that Huygens published his description. I have now to present the class with another *fac simile* of a drawing found among the manuscripts of Huygens, which his friend Bouillau sent him a few days after the former, with the superscription,

Figure de l'Horloge à Pendule qui est à Florence dans le vieux Palais de Medicis, to which Huygens added with his own hand as on the former: *Missum a Ser^o. Pr. Leopoldo ad Ism. Bullialdum, Ao. 1660; cum descriptio Horologii sui edita fuisset, Ao. 1658*. This representation of a public clock on the old Palace of the Medicis, which is of itself sufficiently interesting, when conjoined with the same gentleman's correspondence, bears immediately on the subject under consideration. In the beginning of 1659, he promises to send a description of the clock which was then either undertaken or undergoing repairs by order of the Grand Duke, (*auquel M. le Grand Duc fait travailler*). The following year, when the description was sent, we find allusion to it made in several letters; the words are nearly decisive; in one, the clock which the Grand Duke had got up, (*fait accommoder*); in another, which he had had adjusted, (*fait ajuster*); in a third, which he had had repaired with the pendulum, (*raccommoder avec le pendule, Leyden MS.*) The representation itself, Plate I. Fig. 6. (which I have sometimes suspected to be one of Vincenzo Galileo's old designs perhaps somewhat altered), shows an escapement with a single pallet, as appears in the separate figure of it below, and where it is seen in front. The pendulum appears to be very light, and to describe very great arches. It looks like an imperfect contrivance, and I am in doubts whether it could answer the purpose. The remainder relates to the motion of the hands and the striking.

I shall add as a surprising fact, that Viviani, who wrote the life of Galileo, and set a high value on his reputation, speaks of him only as the inventor of the pendulum, a thing never called in question, but nowhere of the pendulum clock; and this will appear the more surprising, when it is recollected, that Viviani has been cited among the authorities to prove Galileo's claims to the invention. It is true, Tiraboschi, p. 155. afterwards produced a letter said to be written by him in 1673, in which he speaks of this latter claim as a just pretension, (*giusta pretensione*); but, on the other hand, we know that Viviani lived under the same roof with Galileo the three last years of his life; that he worked with him; that the correspondence with the States-General was going on during that time; that he knew of it, and has actually mentioned it (*Vita, p. 78.*); but without a

word of pendulum clocks having been offered to be sent, or been constructed, or even attempted to be constructed;—circumstances which most evidently prove that Viviani did not then consider Galileo as the inventor of pendulum clocks, at least of such clocks as were actually made, and had been proved to answer the purpose for which they were intended.

5. The last circumstance to be considered is the story of Becher's having met with a person who pretended having seen at Prague a pendulum clock made by Justus Borgen, an artist in the service of Rudolph the Second, and under the reign of that Emperor, that is between 1576 and 1612. I suppose Becher's information to have been correct. Then it only follows, that at Prague a clock was seen, bearing the name of Borgen as maker, and having a pendulum. Nor is there any thing wonderful in this; it might be seen in many places, for as the pendulum came to be substituted for the balances in all clocks, public and private, the rest of the work would remain with the maker's name and date, if it had any, unaltered. Thus the clock on the top of the *Stadhuse* (now the Palace) of this city (Amsterdam) had, at the time of Becher's visit to Holland, a perpendicular balance, though, for more than a century, the same work is regulated by means of a very long pendulum. It is even possible that these perpendicular balances, which seem not to have been so common as the horizontal ones (Becher says, having seen them on a large scale *only* here), might be mistaken for pendulums by people not much acquainted with the details of the clockmaker's art. At any rate, if Borgen really constructed the clock such as it was afterwards seen, he must be held the discoverer not merely of the application of the pendulum to clocks, but of the pendulum itself, as a means capable of measuring time; for before 1612 Galileo had published nothing on this subject, nor were pendulums then used by astronomers for that purpose. We know Borgen, or Byrge as he is called by others, to have been an eminent maker of astronomical instruments, and Barthoud, (*Hist. de la Mesure du Temps*, tom. ii. p. 37.), considers it as not improbable that he might have made these discoveries; he says, "Becher is not the only writer who attributes the application of the pendulum to Byrge." I have not been able, with the utmost pains, to discover who these other writers are, and

as he does not mention one, I must consider the assertion as unsupported by any proof. Notwithstanding this, Mr Bode had lately asserted, as an indubitable fact (*Jahrbuch* for 1816), that Byrgius had been intent on the application of the pendulum as early as 1660. So easily are errors copied when once hastily admitted by a writer of eminence !

But with regard to this clock, it is farther added, that Tycho Brahé had made use of it in his astronomical observations. Now Tycho Brahé died in 1600, two years after his *Instaurata Astronomiæ Mechanica* had appeared, in which he describes all his instruments, especially his clocks, complains of the irregularities of the best of them, without ever making mention of single pendulums to measure the time. But I can produce an opposite instance to show, that a clock of Tycho Brahé had actually undergone the alteration before mentioned. The Ambassador of the Court of Denmark at the Hague was in possession of such a clock at the time of Huygens : it bore the date 1576, and had belonged to Tycho Brahé. Huygens, on first seeing it, wrote in his *Adversaria*, which are preserved (*Leyden MSS.*) : “ No mention of pendulums (in Tycho’s *Mechanica*) : On the clock of Mr Crag, the Danish Ambassador, is the year 1576, if I remember right. But if Tycho had already at that time discovered the application of the pendulum, how comes it that he never, during the twenty-four years that he lived after that period, once mentioned in his writings such a valuable and wished for discovery ? I suppose, therefore, that a pendulum was afterwards affixed to Mr Crag’s Tychonian clock, designedly to make it seem as if it had been thus formerly constructed.” A little below we find, and, as the colour of the ink indicates, written on a subsequent occasion : “ That this is really so, the celebrated Roemer, when he came from Denmark to the Hague, has testified to me, and that he knew with certainty when it had been done.” He adds, “ and by whom,” in his manuscript *Anecdota*, where he relates the same again.

In confirmation of his reasoning on the improbability that Tycho being in possession of this capital invention, it should never have become known, I shall farther observe, that the numerous disciples of this astronomer, and the many learned men of every country who visited him, and examined his apparatus,

would infallibly have had some intelligence of it. Among the latter was Blauw, afterwards one of the commissioners appointed by the States to examine Galileo's proposals about the longitude; in their answers, we find remarks on the imperfections of Galileo's proposed pendulum, but not a word of their having ever heard of a better method.

I think it right to inform the class, that among the letters addressed to Huygens, I found one containing a claim to the discovery from a totally different quarter. It is written by Mr Carcavi, a man of rank and merit at Paris, who became one of the first members of the *Academie des Sciences*, at its establishment. He relates having seen an inhabitant of Angouleme, who told him he was in possession of a pendulum clock, made as far back as 1615 or 1616 by a German, for the Queen Marie de Medicis, whose departure, however, had prevented its coming to her; that the artist dying, he had purchased it from his heirs. I mention this as an insulated fact, for as no writer has preserved it, and as subsequent letters of the same gentleman do not allude to it any farther, we have no means of judging whether or not the report deserves any credit at all, and whether what was seen was really a pendulum, by whom it was invented, and how the whole invention came to be buried in oblivion.

Having now gone over the whole evidence, as at first proposed, I believe I shall be warranted in coming to the following conclusions:

That Galileo, after having discovered the properties of the pendulum, and the theory of its vibrations, was likewise the first who showed its use in measuring determinate intervals, and indicating the minute subdivisions of time, an example which was soon followed by all astronomers. That Galileo had thought on a means by which the pendulum might itself indicate the number of oscillations it had performed, without the necessity of counting them, and of course constantly watching it: That he actually conceived the idea of connecting the pendulum with a set of wheels for that purpose, which, however, he only threw out on paper, without putting it in practice, and that he was totally ignorant of the principle of *reciprocal action* between the crown-wheel and pallets, by which the former is regulated, whilst the latter are prevented from returning to rest: That the

labours of his son Vincenzo Galilei were such as never to have led to a decisive or satisfactory result, that they were scarcely known, and never came to the knowledge of Huygens: That the attempts of others seem likewise to have failed of complete success, so that even Hevelius, who approached nearest to it, acknowledges in his *Machina Cælestis*, that, before obtaining it, he was anticipated by another: That it was Huygens who first of all, in December 1656, found out the perfect way of connecting the motion of the pendulum with that of a clock: That he made known the discovery to his numerous correspondents in 1657, published the description, and sent specimens of it everywhere in 1658, and afterwards laboured incessantly to improve upon the adaptation of his principles: That the invention was no sooner known than it was adopted, and balances in a short time removed from all clocks to make room for the pendulum, from which it has happened that many clocks were afterwards found having a pendulum, which nevertheless, by the date, appeared to be of a much earlier construction.

I shall conclude by taking notice of an opinion of the late celebrated Ferdinand Berthoud, expressed in his *Histoire de la Mesure du temps*, p. 101., that Huygens has indeed all the merit we ascribe to him; but that this does not amount to an invention, and he refuses him the rank of inventor, about a contrivance which he contends is nothing but a mere substitution of the pendulum to the balance, the mode of acting by means of pallets being perfectly the same in both. This opinion, which Mr Delambre has already been at some pains to refute, in the *Memoirs of the Institute* for 1808, appears scarcely fair, when it is considered that a great difference exists between balances which acted merely by their inertia, and the pendulum, which is possessed of a principle of motion independent of the clock, and it is farther considered, how admirably this independent motion is combined with that of the clock, regulating instead of disturbing it, and being itself kept in motion by it, without, however, losing any part of its independent rate. Nor was the substitution, as originally made and proposed in the *Horologium*, where the arbor with the pallets stands upright, so obvious or so easily effected, as it afterwards appeared in the improved form given in the *Horologium Oscillatorium*, where the

arbor lies horizontal, and the pendulum takes the place of a perpendicular balance. Mr Berthoud seems to have founded his view of the subject only on a comparison of the latter. The simplicity, too, of the alteration, is rather a proof of ingenuity, especially when we remember that improvements on clocks and pendulums were a favourite theme with the learned at that time.

Notice respecting Plate I. Fig. 5, and 6. These figures are intended to represent the rude sketches sent to Huygens from Florence, through the medium of his friend Bouillau at Paris, and of which complete *fac similes* are added to the original memoir. Those here given, without pretending to the same exactness, are tolerably accurate copies, being reduced to nearly $\frac{1}{34}$ or to between *one-third and one-fourth* of the linear dimensions.—*Translator.*

ART. VI.—*New Inquiries into the Laws which are observed in the Distribution of Vegetable Forms.* By BARON ALEXANDER HUMBOLDT *. (Continued from Vol. VI. p. 289.)

IT is with the distribution of organic beings as with all the other phenomena of the physical world. In the midst of apparent disorder, which seems to arise from the influence of a multitude of local causes, we discover the immutable laws of Nature, as soon as we cast our eyes over a great extent of country, or employ a mass of facts with which the partial disturbances mutually agree. I have had the satisfaction to see this work completed by a minute examination made in Germany, England, Italy, and of late in Denmark. One of the greatest botanists of our times, and indeed of any age, Mr Robert Brown, has compared each of the numerical results with those given by the rich herbaries which he has had the opportunity of consulting. Many of the numbers have been rectified, while the others have been confirmed by an agreement some-

* This continuation is taken from a Memoir read before the Academy of Sciences on the 19th February 1821.